

Bridges Design Diploma

By EngoSoft training center

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Example on calculation prestressing losses

Example on calculation prestressing losses

Example 7.2: Step by step computation of losses in post-tensioned beam

A simply supported post-tensioned beam is shown in the figure below. The area of the prestressing tendons is 1200 mm^2 and $f_{pu}=1900 \text{ N/mm}^2$. Compute the prestressing losses at the critical section of the beam at 100 days knowing that normal stress relieved strands are used inside steel ducts.

Data

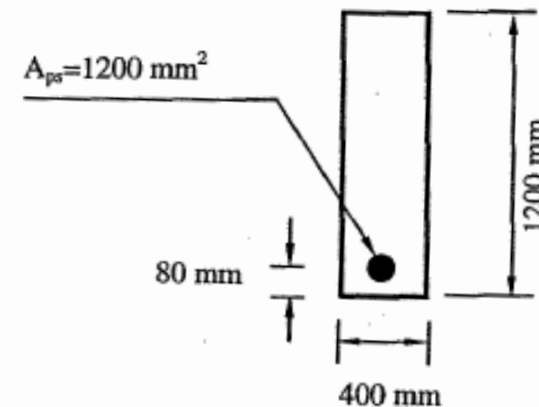
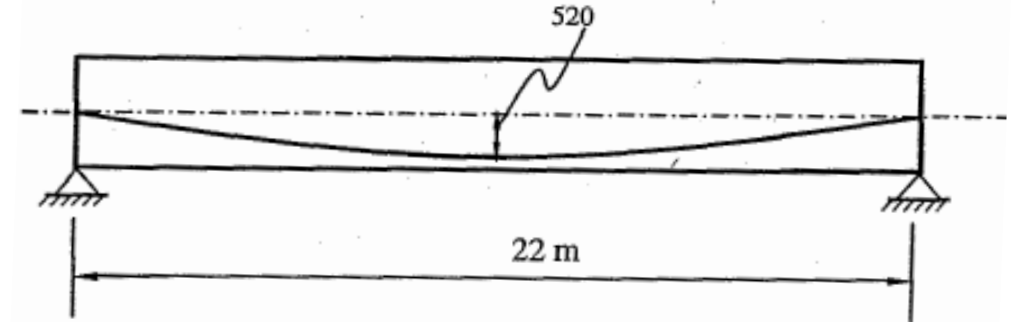
$$w_{DL} = 3.5 \text{ kN/m'}$$

$$f_{cu} = 35 \text{ N/mm}^2$$

$$f_{cui} = 26.25 \text{ N/mm}^2$$

$$E_p = 193000 \text{ N/mm}^2$$

$$\text{Anchorage slip} = 4 \text{ mm}$$



Example on calculation prestressing losses

Step 1: Calculate section properties

$$A = 400 \times 1200 = 480000 \text{ mm}^2$$

$$I = \frac{b \times t^3}{12} = \frac{400 \times 1200^3}{12} = 5.76 \times 10^{10} \text{ mm}^4$$

$$Z_{bot} = Z_{top} = \frac{I}{y_{bot}} = \frac{5.76 \times 10^{10}}{600} = 96 \times 10^6 \text{ mm}^3$$

$$e = 600 - 80 = 520 \text{ mm}$$

$$w_{o.w} = \gamma_c \times A = 25 \times \frac{480000}{1000000} = 12 \text{ kN/m'}$$

For normal relaxation stress relieved stands, the ECP 203 specifies the yield stress as:

$$f_{py} = 0.85 \times f_{pu} = 0.85 \times 1900 = 1615 \text{ N/mm}^2$$

The initial prestressing force at the time of jacking equals:

$$f_{pi} = \text{smaller of} \begin{cases} 0.70 f_{pu} = 0.7 \times 1900 = 1330 \text{ N/mm}^2 \\ 0.80 f_{py} = 0.8 \times 1615 = 1292 \text{ N/mm}^2 \end{cases}$$

$$f_{pi} = 1292 \text{ N/mm}^2$$

Step 2: Anchorage slip Losses

$$\text{The strain due to anchorage slip is } \epsilon_A = \frac{\Delta_A}{L} = \frac{4}{22 \times 1000} = 1.818 \times 10^{-4}$$

The loss in stresses due to anchorage slip is given by:

$$\Delta f_{pA} = \epsilon_A \times E_{ps} = 1.818 \times 10^{-4} \times 193000 = 35.09 \text{ N/mm}^2$$

Example on calculation prestressing losses

Step 3: Wobble friction losses

The code specifies $k=0.0033$ for normal conditions, thus the stress at the end of the beam equals:

$$P_{x1} = P_o \cdot e^{-k \cdot x} = 1292 \cdot e^{(-0.0033 \times 22)} = 1201.5 \text{ N/mm}^2$$

$$\text{Losses} = 1292 - 1201.525 = 90.47 \text{ N/mm}^2$$

Step 4: Curvature friction losses

The radius of curvature r_{ps} can be approximated by:

$$r_{ps} \approx \frac{L^2}{8 \times e} = \frac{22^2}{8 \times (520/1000)} = 116.35 \text{ m}$$

The stress after frictional losses equals:

$$P_{x2} = P_o \cdot e^{\left(-\frac{\mu \cdot x}{r_{ps}}\right)} = 1292 \cdot e^{\left(-\frac{0.3 \times 22}{116.35}\right)} = 1220.75 \text{ N/mm}^2$$

$$\text{Losses} = 1292 - 1220.75 = 71.25 \text{ N/mm}^2$$

$$\text{Total frictional losses} = \Delta f_{pf} = 90.47 + 71.25 = 161.73 \text{ N/mm}^2$$

$$\text{Net force} = P_x = 1292 - 161.73 = 1095.18 \text{ N/mm}^2$$

Example on calculation prestressing losses

Step 5: Elastic shortening losses

The modulus of elasticity at the time of prestressing E_{ci} equals:

$$E_{ci} = 4400\sqrt{f_{ci}} = 4400\sqrt{26.25} = 22543.3 \text{ N/mm}^2$$

At transfer, the beam self weight is the only acting moment that equals:

$$M_{ow} = \frac{w_{ow} \times L^2}{8} = \frac{12 \times 22^2}{8} = 726 \text{ kN.m}$$

The Total losses including (anchorage + Wobble + friction losses) equals:

$$= 35.09 + 161.73 = 196.82 \text{ N/mm}^2$$

Net prestressing stress = $1292 - 196.82 = 1095.18 \text{ N/mm}^2$

$$P_i = f_{pi} \times A_{ps} = \frac{1095.18 \times 1200}{1000} = 1314.22 \text{ kN}$$

The concrete stress at the level of the prestressing tendons is given by:

$$f_{pci} = -\frac{P_i}{A} - \frac{P_i \times e \times e}{I} + \frac{M_{ow} \times e}{I}$$

$$f_{pci} = -\frac{1314.22 \times 1000}{480000} - \frac{1314.22 \times 1000 \times 520 \times 520}{5.76 \times 10^{10}} + \frac{726 \times 10^6 \times 520}{5.76 \times 10^{10}}$$

$$f_{pci} = -2.35 \text{ N/mm}^2$$

The loss of prestressing force due to elastic shortening is given by:

$$\Delta f_{pe} = \frac{E_p}{E_{ci}} f_{pci} = \frac{193000}{22543.29} 2.35 = 20.15 \text{ N/mm}^2$$

$$f_{pi} = 1095.18 - 20.15 = 1075.03 \text{ N/mm}^2$$

Example on calculation prestressing losses

Step 6: Calculation of creep losses

$$P_i = f_{pi} \times A_{ps} = \frac{1075.03 \times 1200}{1000} = 1290.04 \text{ kN}$$

The modulus of elasticity of concrete at full strength:

$$E_c = 4400 \sqrt{f_{cu}} = 4400 \sqrt{35} = 26030.7 \text{ N/mm}^2$$

The moment due to the superimposed dead loads equals:

$$M_{sd} = \frac{w_{sd} L^2}{8} = \frac{3.5 \times 22^2}{8} = 211.75 \text{ kN.m}$$

The additional stress due to this load is given by:

$$f_{csd}^* = \frac{M_{sd} \times e}{I} = \frac{211.75 \times 10^6 \times 520}{5.76 \times 10^{10}} = 1.91 \text{ N/mm}^2$$

$$f_{cs}^* = -\frac{1290.04 \times 1000}{480000} - \frac{1290.04 \times 1000 \times 520^2}{5.76 \times 10^{10}} + \frac{726 \times 10^6 \times 520}{5.76 \times 10^{10}} = -2.19 \text{ N/mm}^2$$

For post-tensioned beams, $\phi=1.6$. The creep loss equals:

$$\Delta f_{pcr} = \phi \frac{E_p}{E_c} (f_{cs}^* - f_{csd}^*) = 1.6 \frac{193000}{26030.7} (2.19 - 1.91) = 3.30 \text{ N/mm}^2$$

Step 7: Calculation of shrinkage losses

For post-tensioned beams, the shrinkage strain ϵ_{sh} is 200×10^{-6} .

$$\Delta f_{psh} = \epsilon_{sh} \times E_p = 200 \times 10^{-6} \times 193000 = 38.6 \text{ N/mm}^2$$

Step 4: Calculation of steel relaxation losses

$K_1=10$ for normal stress relieved tendons & $t=100$ day = $100 \times 24 = 2400$ hours.

The code requires calculating the relaxation losses at a time not exceeding 1000 hours. Thus, $t = 1000$ hour.

$$\Delta f_{pr} = \frac{f_{pi} \times \log(t)}{K_1} \left(\frac{f_{pi}}{f_{py}} - 0.55 \right)$$

$$\Delta f_{pr} = \frac{1075.03 \times \log(1000)}{10} \left(\frac{1075.03}{1615} - 0.55 \right) = 37.30 \text{ N/mm}^2$$

Example on calculation prestressing losses

The itemized losses can be summarized in the following table

Type	Stress (N/mm ²)	% of total losses
Anchorage slip losses	35.09	11.8%
Wobble friction losses	90.48	30.5%
Curvature friction losses	71.25	24.1%
Elastic shortening	20.15	6.8%
Shrinkage losses	38.60	13.0%
Creep losses	3.30	1.1%
Relaxation losses	37.30	12.6%
Total immediate losses	216.97	73.3%
Total time dependent losses	79.20	26.7%
Total losses	296.16	100.0%
Stress before losses	1292	
Stress after losses	995.84	
Losses (%)	22.92%	

Refined Calculation of time – dependent Losses Based on AASHTO LRFD (Cl. 5.9.5.4)

Refined Calculation of time – dependent Losses (AASHTO)



Refined method to estimate of Time-Dependent Losses

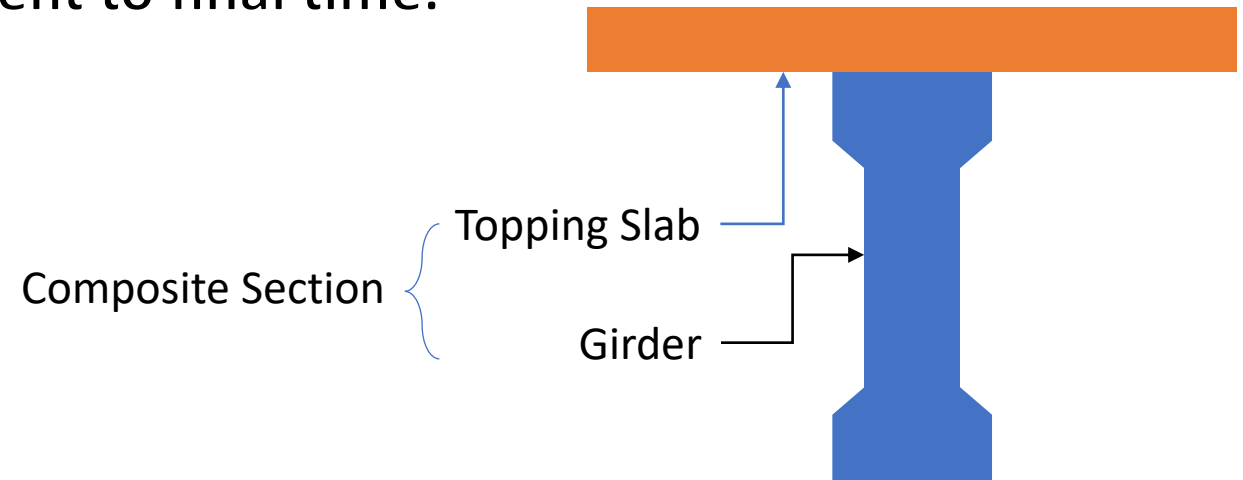
- AASHTO LRFD specified a method to calculate more accurate values of creep, shrinkage and relaxation than those specified in the approximate method.
- This method could be found in AASHTO LRFD under the clause 5.9.5.4.
- It's a combination of equations in serial to finally get the value of time dependent losses of prestressing.
- In the following slides will be shown a fast look on these equations.

Refined Calculation of time – dependent Losses (AASHTO)



Refined method to estimate of Time-Dependent Losses

- Time dependent losses as per refined method are divided into two stages as per time:
 - Losses from time of transfer (transfer of prestressing force to precast girder) to time of deck placement.
 - Losses from time of deck placement to final time.



Refined Calculation of time – dependent Losses (AASHTO)



Refined method to estimate of Time-Dependent Losses

For nonsegmental prestressed members, more accurate values of creep-, shrinkage-, and relaxation-related losses, than those specified in Article 5.9.5.3 may be determined in accordance with the provisions of this Article. For precast pretensioned girders without a composite topping and for precast or cast-in-place nonsegmental post-tensioned girders, the provisions of Articles 5.9.5.4.4 and 5.9.5.4.5, respectively, shall be considered before applying the provisions of this Article.

The change in prestressing steel stress due to time-dependent loss, Δf_{pLT} , shall be determined as follows:

$$\Delta f_{pLT} = (\Delta f_{pSR} + \Delta f_{pCR} + \Delta f_{pR1})_{id} + (\Delta f_{pSD} + \Delta f_{pCD} + \Delta f_{pR2} - \Delta f_{pSS})_{df} \quad (5.9.5.4.1-1)$$

where:

Δf_{pSR} = prestress loss due to shrinkage of girder concrete between transfer and deck placement (MPa)

Δf_{pCR} = prestress loss due to creep of girder concrete between transfer and deck placement (MPa)

Δf_{pR1} = prestress loss due to relaxation of prestressing strands between time of transfer and deck placement (MPa)

Δf_{pR2} = prestress loss due to relaxation of prestressing strands in composite section between time of deck placement and final time (MPa)

5.9.5.4.5—Post-Tensioned Nonsegmental Girders

Long-term prestress losses for post-tensioned members after tendons have been grouted may be calculated using the provisions of Articles 5.9.5.4.1 through 5.9.5.4.4. In Eq. 5.9.5.4.1-1, the value of the term $(\Delta f_{pSR} + \Delta f_{pCR} + \Delta f_{pR1})_{id}$ shall be taken as zero.

Δf_{pSD} = prestress loss due to shrinkage of girder concrete between time of deck placement and final time (MPa)

Δf_{pCD} = prestress loss due to creep of girder concrete between time of deck placement and final time (MPa)

Δf_{pSS} = prestress gain due to shrinkage of deck in composite section (MPa)

$(\Delta f_{pSR} + \Delta f_{pCR} + \Delta f_{pR1})_{id}$
= sum of time-dependent prestress losses between transfer and deck placement (MPa)

$(\Delta f_{pSD} + \Delta f_{pCD} + \Delta f_{pR2} - \Delta f_{pSS})_{df}$
= sum of time-dependent prestress losses after deck placement (MPa)

Refined Calculation of time – dependent Losses (AASHTO)



Shrinkage of Girder (time of transfer to time of deck placement)

5.9.5.4.2 Losses: Time of Transfer to Time of Deck Placement

5.9.5.4.2a Shrinkage of Girder Concrete

The prestress loss due to shrinkage of girder concrete between time of transfer and deck placement, Δf_{pSR} , shall be determined as:

$$\Delta f_{pSR} = \varepsilon_{bid} E_p K_{id} \quad (5.9.5.4.2a-1)$$

in which:

$$K_{id} = \frac{1}{1 + \frac{E_p}{E_{ci}} \frac{A_{ps}}{A_g} \left(1 + \frac{A_g e_{pg}^2}{I_g} \right) [1 + 0.7 \Psi_b(t_f, t_i)]} \quad (5.9.5.4.2a-2)$$

where:

ε_{bid} = concrete shrinkage strain of girder between the time of transfer and deck placement per Eq. 5.4.2.3.3-1

K_{id} = transformed section coefficient that accounts for time-dependent interaction between concrete and bonded steel in the section being considered for time period between transfer and deck placement

e_{pg} = eccentricity of prestressing force with respect to centroid of girder (mm); positive in common construction where it is below girder centroid

$\Psi_b(t_f, t_i)$ = girder creep coefficient at final time due to loading introduced at transfer per Eq. 5.4.2.3.2-1

t_f = final age (days)

t_i = age at transfer (days)

Refined Calculation of time – dependent Losses (AASHTO)



Shrinkage of Girder (time of transfer to time of deck placement)

where:

ϵ_{bid} = concrete shrinkage strain of girder between the time of transfer and deck placement per Eq. 5.4.2.3.3-1

5.4.2.3.3 Shrinkage

For concretes devoid of shrinkage-prone aggregates, the strain due to shrinkage, ϵ_{sh} , at time, t , may be taken as:

$$\epsilon_{sh} = k_s k_{hs} k_f k_{td} 0.48 \times 10^{-3} \quad (5.4.2.3.3-1)$$

in which:

$$k_{hs} = (2.00 - 0.014 H) \quad (5.4.2.3.3-2)$$

where:

k_{hs} = humidity factor for shrinkage

$$k_s = 1.45 - 0.0051(V/S) \geq 1.0 \quad (5.4.2.3.2-2)$$

$$k_f = \frac{35}{7 + f'_{ci}} \quad (5.4.2.3.2-4)$$

$$k_{td} = \left(\frac{t}{61 - 0.58 f'_{ci} + t} \right) \quad (5.4.2.3.2-5)$$

t_i = age of concrete at time of load application (day)

V/S = volume-to-surface ratio (mm)

f'_{ci} = specified compressive strength of concrete at time of prestressing for pretensioned members and at time of initial loading for nonprestressed members. If concrete age at time of initial loading is unknown at design time, f'_{ci} may be taken as $0.80 f'_c$ (MPa).

where:

H = relative humidity (%). In the absence of better information, H may be taken from Figure 5.4.2.3.3-1.

k_s = factor for the effect of the volume-to-surface ratio of the component

k_f = factor for the effect of concrete strength

k_{hc} = humidity factor for creep

k_{td} = time development factor

t = maturity of concrete (day), defined as age of concrete between time of loading for creep calculations, or end of curing for shrinkage calculations, and time being considered for analysis of creep or shrinkage effects

Refined Calculation of time – dependent Losses (AASHTO)



Shrinkage of Girder (time of transfer to time of deck placement)

$\Psi_b(t_f, t_i)$ = girder creep coefficient at final time due to loading introduced at transfer per Eq. 5.4.2.3.2-1

$$\Psi(t, t_i) = 1.9 k_s k_{hc} k_f k_{td} t_i^{-0.118} \quad (5.4.2.3.2-1)$$

for which:

$$k_s = 1.45 - 0.0051(V/S) \geq 1.0 \quad (5.4.2.3.2-2)$$

$$k_{hc} = 1.56 - 0.008H \quad (5.4.2.3.2-3)$$

$$k_f = \frac{35}{7 + f'_{ci}} \quad (5.4.2.3.2-4)$$

$$k_{td} = \left(\frac{t}{61 - 0.58 f'_{ci} + t} \right) \quad (5.4.2.3.2-5)$$

where:

H = relative humidity (%). In the absence of better information, H may be taken from Figure 5.4.2.3.3-1.

k_s = factor for the effect of the volume-to-surface ratio of the component

k_f = factor for the effect of concrete strength

k_{hc} = humidity factor for creep

k_{td} = time development factor

t = maturity of concrete (day), defined as age of concrete between time of loading for creep calculations, or end of curing for shrinkage calculations, and time being considered for analysis of creep or shrinkage effects

t_i = age of concrete at time of load application (day)

V/S = volume-to-surface ratio (mm)

f'_{ci} = specified compressive strength of concrete at time of prestressing for pretensioned members and at time of initial loading for nonprestressed members. If concrete age at time of initial loading is unknown at design time, f'_{ci} may be taken as $0.80 f'_c$ (MPa).

The surface area used in determining the volume-to-surface ratio should include only the area that is exposed to atmospheric drying. For poorly ventilated enclosed cells, only 50 percent of the interior perimeter should be used in calculating the surface area. For precast members with cast-in-place topping, the total precast surface should be used. For pretensioned stemmed members (I-beams, T-beams, and box beams), with an average web thickness of 150 to 200 mm, the value of k_{vs} may be taken as 1.00.

Refined Calculation of time – dependent Losses (AASHTO)



Creep of Girder (time of transfer to time of deck placement)

5.9.5.4.2b Creep of Girder Concrete

The prestress loss due to creep of girder concrete between time of transfer and deck placement, Δf_{pCR} , shall be determined as:

$$\Delta f_{pCR} = \frac{E_p}{E_{ci}} f_{cgp} \psi_b(t_d, t_i) K_{id} \quad (5.9.5.4.2b-1)$$

where:

$\Psi_b(t_d, t_i)$ = girder creep coefficient at time of deck placement due to loading introduced at transfer per Eq. 5.4.2.3.2-1

t_d = age at deck placement (days)

Refined Calculation of time – dependent Losses (AASHTO)



Relaxation of prestressing strands (time of transfer to time of deck placement)

5.9.5.4.2c Relaxation of Prestressing Strands

The prestress loss due to relaxation of prestressing strands between time of transfer and deck placement, Δf_{pR1} , shall be determined as:

$$\Delta f_{pR1} = \frac{f_{pt}}{K_L} \left(\frac{f_{pt}}{f_{py}} - 0.55 \right) \quad (5.9.5.4.2c-1)$$

where:

f_{pt} = stress in prestressing strands immediately after transfer, taken not less than $0.55f_{py}$ in Eq. 1

K_L = 30 for low relaxation strands and 7 for other prestressing steel, unless more accurate manufacturer's data are available

The relaxation loss, Δf_{pR1} , may be assumed equal to 8 MPa for low-relaxation strands.

Refined Calculation of time – dependent Losses (AASHTO)

Shrinkage of Girder (time of Deck placement to final time)

5.9.5.4.3a Shrinkage of Girder Concrete

The prestress loss due to shrinkage of girder concrete between time of deck placement and final time, Δf_{pSD} , shall be determined as:

$$\Delta f_{pSD} = \epsilon_{bdf} E_p K_{df} \quad (5.9.5.4.3a-1)$$

in which:

$$K_{df} = \frac{1}{1 + \frac{E_p}{E_{ci}} \frac{A_{ps}}{A_c} \left(1 + \frac{A_c e_{pc}^2}{I_c} \right) [1 + 0.7 \psi_b(t_f, t_i)]} \quad (5.9.5.4.3a-2)$$

where:

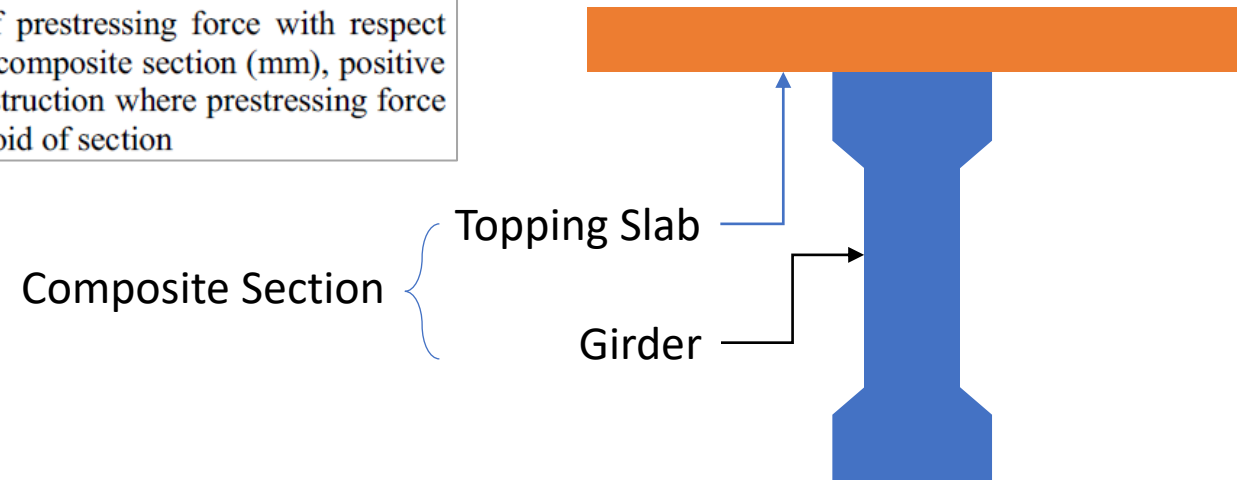
ϵ_{bdf} = shrinkage strain of girder between time of deck placement and final time per Eq. 5.4.2.3.3-1

K_{df} = transformed section coefficient that accounts for time-dependent interaction between concrete and bonded steel in the section being considered for time period between deck placement and final time

e_{pc} = eccentricity of prestressing force with respect to centroid of composite section (mm), positive in typical construction where prestressing force is below centroid of section

A_c = area of section calculated using the gross composite concrete section properties of the girder and the deck and the deck-to-girder modular ratio (mm^2)

I_c = moment of inertia of section calculated using the gross composite concrete section properties of the girder and the deck and the deck-to-girder modular ratio at service (mm^4)



Refined Calculation of time – dependent Losses (AASHTO)



Creep of Girder (time of Deck placement to final time)

5.9.5.4.3b—Creep of Girder Concrete

The prestress (loss is positive, gain is negative) due to creep of girder concrete between time of deck placement and final time, Δf_{pCD} , shall be determined as:

$$\Delta f_{pCD} = \frac{E_p}{E_{ci}} f_{cgp} \left[\psi_b(t_f, t_i) - \psi_b(t_d, t_i) \right] K_{df} + \frac{E_p}{E_c} \Delta f_{cd} \psi_b(t_f, t_d) K_{df} \quad (5.9.5.4.3b-1)$$

where:

Δf_{cd} = change in concrete stress at centroid of prestressing strands due to long-term losses between transfer and deck placement, combined with deck weight and superimposed loads (ksi)

$\Psi_b(t_f, t_d)$ = girder creep coefficient at final time due to loading at deck placement per Eq. 5.4.2.3.2-1

Refined Calculation of time – dependent Losses (AASHTO)



Relaxation of prestressing strands (time of Deck placement to final time)

5.9.5.4.3c Relaxation of Prestressing Strands

The prestress loss due to relaxation of prestressing strands in composite section between time of deck placement and final time, Δf_{pR2} , shall be determined as:

$$\Delta f_{pR2} = \Delta f_{pR1} \quad (5.9.5.4.3c-1)$$

Refined Calculation of time – dependent Losses (AASHTO)



Shrinkage of deck concrete (time of Deck placement to final time)

5.9.5.4.3d—Shrinkage of Deck Concrete

The prestress gain due to shrinkage of deck composite section, Δf_{pSS} , shall be determined as:

$$\Delta f_{pSS} = \frac{E_p}{E_c} \Delta f_{cdf} K_{df} \left[1 + 0.7 \Psi_b(t_f, t_d) \right] \quad (5.9.5.4.3d-1)$$

$$\Delta f_{cdf} = \frac{\epsilon_{ddf} A_d E_{cd}}{\left[1 + 0.7 \Psi_b(t_f, t_d) \right]} \left(\frac{1}{A_c} - \frac{e_{pc} e_d}{I_c} \right) \quad (5.9.5.4.3d-2)$$

where:

- Δf_{cdf} = change in concrete stress at centroid of prestressing strands due to shrinkage of deck concrete (MPa)
- ϵ_{ddf} = shrinkage strain of deck concrete between placement and final time per Eq. 5.4.2.3.3-1
- A_d = area of deck concrete (mm²)
- E_{cd} = modulus of elasticity of deck concrete (MPa)
- e_d = eccentricity of deck with respect to the gross composite section, positive in typical construction where deck is above girder (mm)
- $\Psi_b(t_f, t_d)$ = creep coefficient of deck concrete at final time due to loading introduced shortly after deck placement (i.e. overlays, barriers, etc.) per Eq. 5.4.2.3.2-1

Refined Calculation of time – dependent Losses Based on CEB-FIP

Refined Calculation of time – dependent Losses (CEB-FIP)



Refined method to estimate of Time-Dependent Losses

- We use CSI-Bridge software to calculate the Time-dependent losses of prestressing based on CEB-FIP.
- It's a serial of equations more likely to that illustrated on the AASHTO LRFD method.

How To get long Term losses from CSI-Bridge software

How To get long Term losses from CSI-Bridge software

Define parameter of material time dependent properties

(c) Effect of type of cement and curing temperature

The effect of the type of cement on the creep coefficient of concrete may be taken into account by modifying the age at loading t_0 to $t_{0, adj}$:

$$t_{0, adj} = t_{0,T} \cdot \left[\frac{9}{2 + t_{0,T}^{1.2}} + 1 \right]^{\alpha} \geq 0.5 \text{ days} \quad (5.1-73)$$

where:

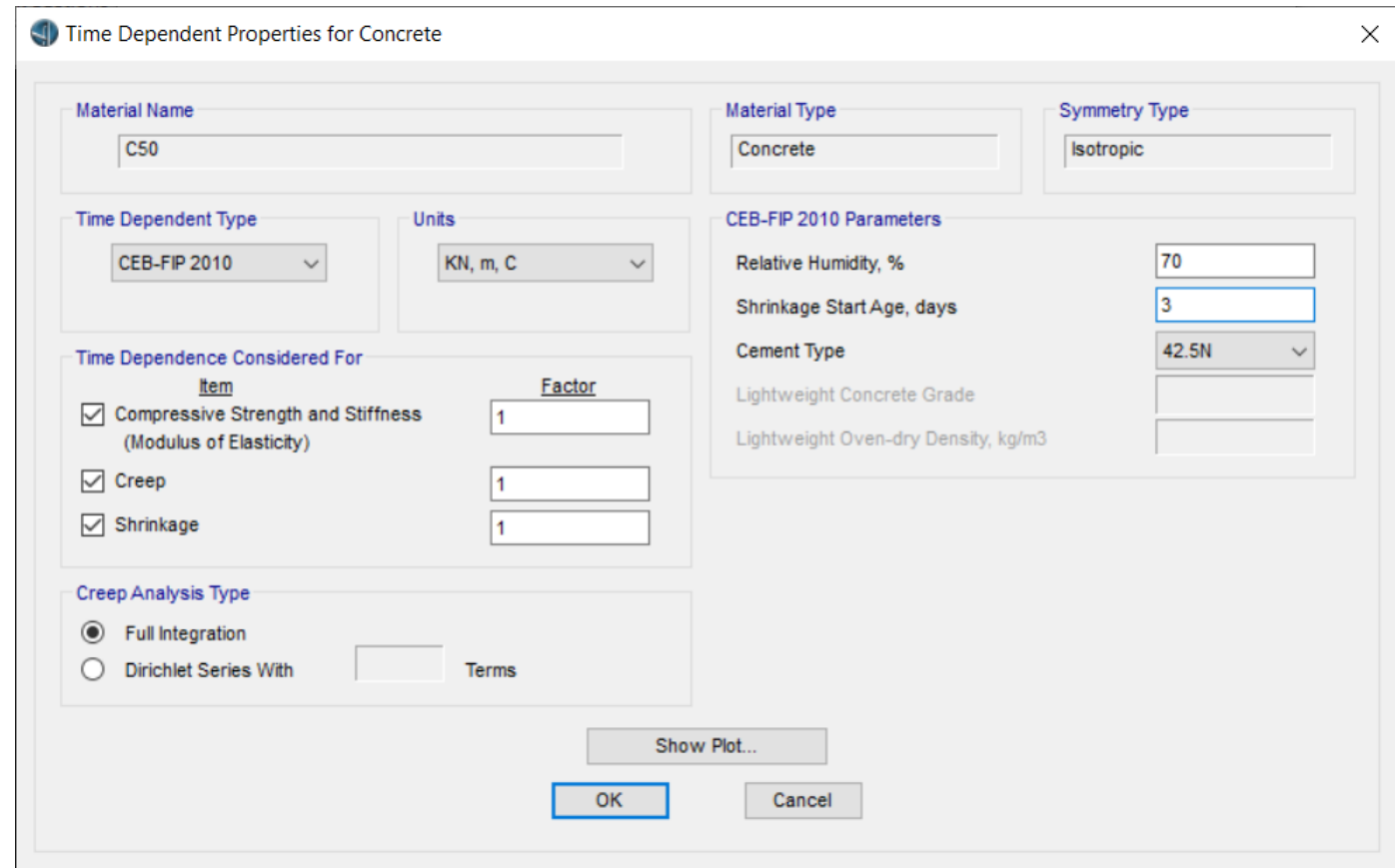
$t_{0,T}$ is the age of concrete at loading in days adjusted according to Eq. (5.1-85);

α is a coefficient which depends on the type of cement:

$\alpha = -1$ for strength class 32.5 N;

$\alpha = 0$ for strength classes 32.5 R, 42.5 N;

$\alpha = 1$ for strength classes 42.5 R, 52.5 N, 52.5 R.



Time Dependent Properties for Concrete

Material Name: C50

Material Type: Concrete

Symmetry Type: Isotropic

Time Dependent Type: CEB-FIP 2010

Units: KN, m, C

CEB-FIP 2010 Parameters

Relative Humidity, %: 70

Shrinkage Start Age, days: 3

Cement Type: 42.5N

Lightweight Concrete Grade:

Lightweight Oven-dry Density, kg/m3:

Time Dependence Considered For

Item	Factor
☒ Compressive Strength and Stiffness (Modulus of Elasticity)	1
☒ Creep	1
☒ Shrinkage	1

Creep Analysis Type

☒ Full Integration

☐ Dirichlet Series With Terms

Show Plot...

OK Cancel

How To get long Term losses from CSI-Bridge software



Prestressing Material

- Number 2 for low-relaxation strands

Time Dependent Properties for Tendons

Material Name: A416Gr270

Material Type: Tendon

Symmetry Type: Uniaxial

Time Dependent Type: ☒ CEB-FIP 90

Units: KN, m, C

CEB-FIP Parameters: CEB-FIP Class: 2

Time Dependence Considered For:

Item	Factor
☒ Prestressing Steel Relaxation	1

Relaxation Analysis Type:

☒ Full Integration

☐ Dirichlet Series With Terms

Show Plot...

OK Cancel

Prestressing Profile criterial and requirements

Prestressing Profile criterial and requirements



Force per strand and jacking force:

- In our region of MENA we mostly uses the ASTM A416-06 Grade 270 type of strands.
- And all the time we use 15 mm strands (0.6") whenever it is available.

1.1 Strand Properties 15 mm (0.6")

Strand type			prEN 10138 – 3 (2009)			ASTM A 416-06 Grade 270
			Y1860S7	Y1860S7	Y1770S7	
Nominal diameter	d	(mm)	15.3	15.7	15.7	15.24
Nominal cross section	A _p	(mm ²)	140	150	150	140
Nominal mass	M	(kg/m)	1.093	1.172	1.172	1.102
Nominal yield strength	f _{p0,1k}	(MPa)	1636 ¹⁾	1640 ¹⁾	1526 ¹⁾	1676 ²⁾
Nominal tensile strength	f _{pk}	(MPa)	1860	1860	1770	1860
Specif./min. breaking load	F _{pk}	(kN)	260.4	279.0	265.5	260.7
Young's modulus		(GPa)	approx. 195			
Relaxation ³⁾ after 1000 h at 20 °C and 0.7 x F _{pk}		(%)	max. 2.5			

Prestressing Profile criterial and requirements



Force per strand and jacking force:

- the AASHTO LRFD define the maximim tension force in a post-tension tendons, which should generally not be exceeded.
- So the maximum jacking force of any strand = $0.75 * 260.7 = 195.525 \text{ kN/strand}$

Nominal tensile strength	f_{pk}	(MPa)	1860	1860	1770	1860
Specif./min. breaking load	F_{pk}	(kN)	260.4	279.0	265.5	260.7
Young's modulus		(GPa)	approx. 195			
Relaxation ³⁾ after 1000 h at 20 °C and $0.7 \times F_{pk}$		(%)	max. 2.5			

STANDARD	Max. force AFTER transfer of prestressing force to the concrete	Max. force BEFORE transfer of prestressing force to the concrete
FIB Model Code 2010	Min ($0.75 f_{pk}$; $0.85 f_{p0.1k}$)	Min ($0.80 f_{pk}$; $0.90 f_{p0.1k}$)
Eurocode 2 (EN-1992-1-1)	Min ($0.75 f_{pk}$; $0.85 f_{p0.1k}$)	Min ($0.80 f_{pk}$; $0.90 f_{p0.1k}$)
AASHTO LRFD Bridge Design Specification 2010	$0.70 f_{pk}$ (at anchorage) / $0.74 f_{pk}$ (along tendon)	$0.75 f_{pk}$

Prestressing Profile criterial and requirements

Preliminary estimation of prestressing jacking force

- Fast estimation of prestressing jacking force is based on average prestressing stress prior any losses on the deck cross section.
- This stress $\approx 8.00 \text{ MPa (N/mm}^2\text{)}$.
- So; $\frac{n f_{pk} * 0.75}{A} = 8.00 \text{ N/mm}^2 = 8000 \text{ kN/m}^2$
- $n = \frac{8000}{260.7 * 0.75} \times A = 42 A$
- Where;
 - A is the area of the cross section in METERS.

Prestressing Profile criterial and requirements



Specify the number of tendons

- After we specify the preliminary number of strands, get the proper number of ducts by dividing the number of strands on the number of strands/duct.
- The number of duct shall be symmetric in the section

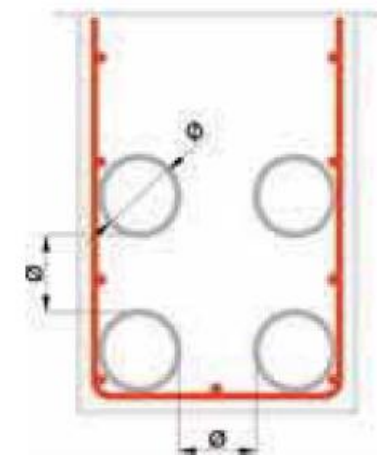
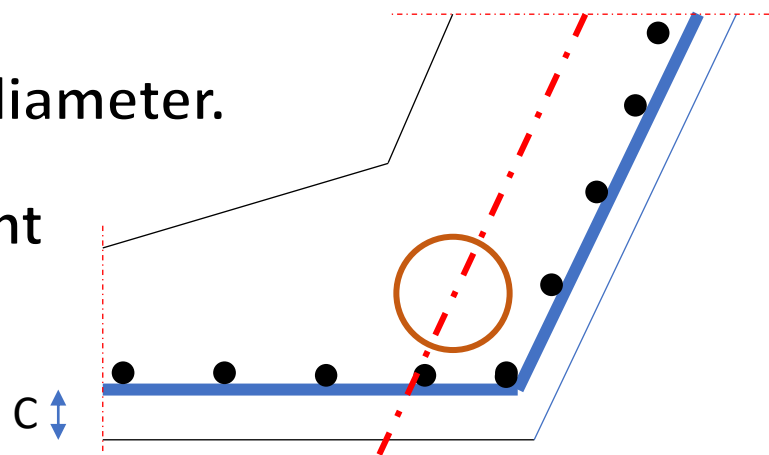
1.2 Tendon Properties 15 mm (0.6") and corresponding duct diameters

Unit	Strands numbers	Breaking load				Steel duct ⁴⁾				Plastic duct VSL PT-PLUS®		PE pipe	
		Y1860S7 (prEN)		Y1770S7 (prEN)	Grade 270 (ASTM)	minimum		recommended		Ø _i / Ø _a ⁵⁾	e	Ø _{ext} x t _{min}	e
		d=15.3 mm A _p =140 mm ²	d=15.7 mm A _p =150 mm ²	d=15.7 mm A _p =150 mm ²	d=15.24 mm A _p =140 mm ²	Ø _i / Ø _a	e	Ø _i / Ø _a	e				
		[kN]	[kN]	[kN]	[kN]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm x mm]	[mm]
6-1	1	260	279	265.5	260.7	25/30	5	30/35	7	22/25	6	25 x 2.0	3
6-2	2	520	558	531	521	40/45	9	45/50	12	²⁾	-	40 x 3.0	6
6-3	3	780	837	797	782	40/45	6	45/50	9	²⁾	-	50 x 3.7	8
6-4	4	1040	1116	1062	1043	45/50 ¹⁾	7	50/55 ¹⁾	10	²⁾	-	50 x 3.7	6
6-7	5	1300	1395	1328	1304	50/57	8	55/60	11	58/63 ²⁾	-	75 x 5.6	17
6-7	6	1560	1674	1593	1564	55/62	9	60/67	12	58/63	11	75 x 5.6	15
	7	1820	1953	1859	1825	55/62	7	60/67	10	65/70	14	75 x 5.6	13
6-12	8	2080	2232	2124	2086	65/72	11	70/77	14	76/81	18	90 x 5.4	20
6-12	9	2340	2511	2390	2346	65/72	9	70/77	12	76/81	16	90 x 5.4	18
	10	2600	2790	2655	2607	70/77	11	75/82	14	76/81	15	90 x 5.4	17
6-12	11	2860	3069	2921	2868	70/77	9	75/82	12	76/81	13	90 x 5.4	15
	12	3120	3348	3186	3128	75/82	11	80/87	14	76/81	12	90 x 5.4	14
6-15	13	3380	3627	3452	3389	80/87	13	85/92	16	85/91	16	110 x 5.3	26
6-15	14	3640	3906	3717	3650	80/87	11	85/92	14	85/91	16	110 x 5.3	25
	15	3900	4185	3983	3911	80/87	10	85/92	13	85/91	12	110 x 5.3	24
6-19	16	4160	4464	4248	4171	85/92	12	90/97	15	100/106	22	110 x 5.3	22
6-19	17	4420	4743	4514	4432	85/92	11	90/97	14	100/106	20	110 x 5.3	20
	18	4680	5022	4779	4693	90/97	13	95/102	16	100/106	19	110 x 5.3	19
6-19	19	4940	5301	5045	4953	90/97	12	95/102	15	100/106	18	110 x 5.3	18
6-22	20	5200	5580	5310	5214	100/107	17	110/117	23	100/106	17	125 x 6.0	24
6-22	21	5460	5859	5576	5475	100/107	16	110/117	22	100/106	16	125 x 6.0	23
	22	5720	6138	5841	5735	100/107	15	110/117	21	100/106	15	125 x 6.0	22
6-27	23	5980	6417	6107	5996	100/107	14	110/117	20	115/121	22	125 x 6.0	21

Prestressing Profile criterial and requirements

Specify tendons spacing and concrete cover.

- Minimum spacing between ducts is the OUTER duct diameter.
- The minimum clear cover from any concrete edge shall be calculated based on the following:
 - The RFT cover (C) which is based on many parameters like (class of exposure, bond and fire resistance)
 - The outer transfers reinforcement diameter.
 - The outer longitudinal reinforcement diameter.



Prestressing Profile criterial and requirements

Anchorage Type.

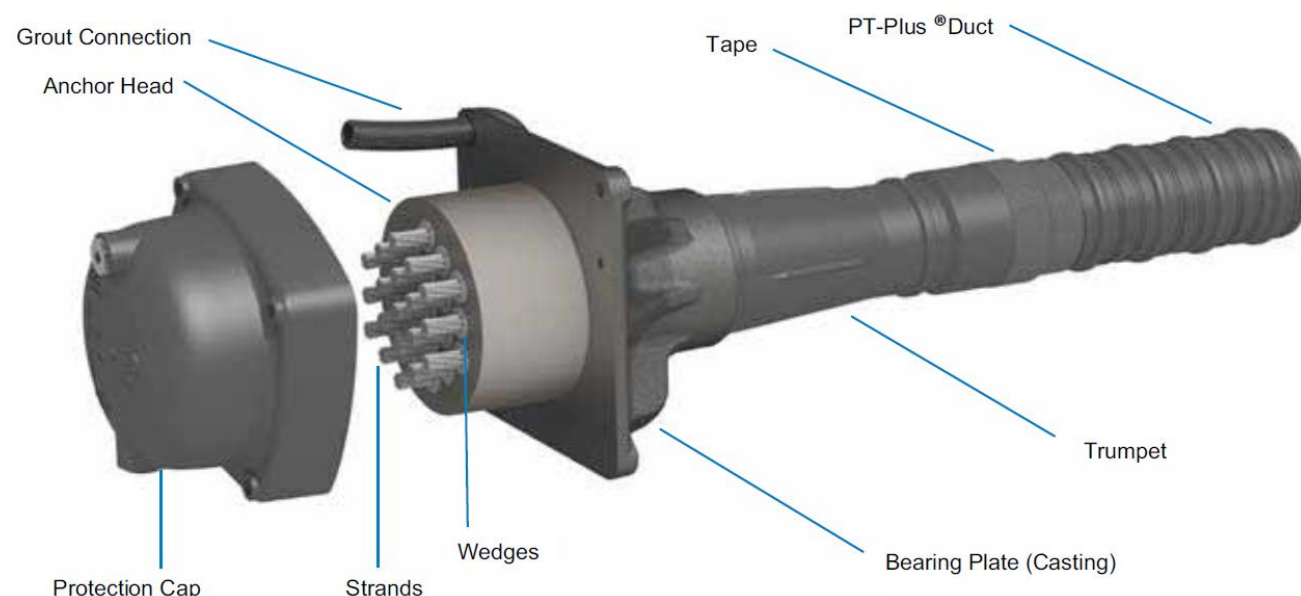
- There are many types of anchorage, but here in MENA region The GC type from VSL is the most used type (as recommended by VSL).

Live (stressing) anchorages

(also used as dead-end anchorages)

GC anchorage

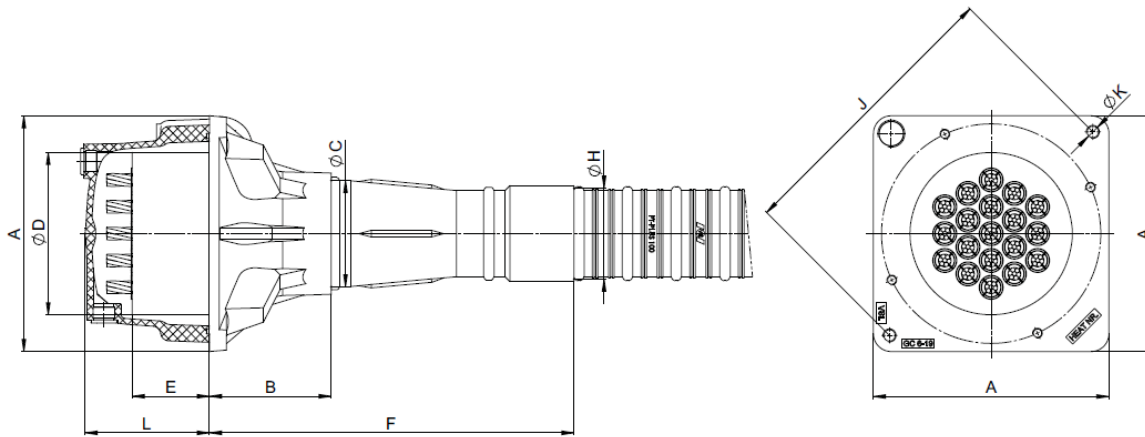
- The most economical VSL anchorage for multistrand applications
- Compact and easy to handle anchorage system
- Units ranging from 6-3 to 6-55



Prestressing Profile criterial and requirements

Anchorage Type.

- The dimension of each size is specified as per the table that could be found in vendor catalog.



Unit	□A	B	ØC	ØD	E	F	ØH ⁽²⁾	J ⁽¹⁾	ØK	L
6-3	130	120	50	95	50	120	50	140	M12	105
6-4	140	120	60	110	55	120	60	154	M12	110
6-7	180	135	76	135	60	135	69	210	M12	120
6-12	230	220	92	170	75	220	92	264	M16	135
6-15	260	240	113	190	85	240	113	316	M16	145
6-19	290	150	131	200	95	450	112	354	M16	155
6-22	320	150	153	220	100	640	112	400	M16	160
6-27	350	170	164	240	110	620	127	430	M16	170
6-31	375	170	173	260	120	580	143	470	M16	180
6-37	410	170	196	280	135	770	142	524	M16	200
6-43	470	180	230	320	145	935	166	420	M20	215
6-55	520	180	240	340	160	1035	166	452	M20	230

Prestressing Profile criterial and requirements

Anchorage Type.

Multistrand Post-Tensioning System

Internal Bonded Post-Tensioning

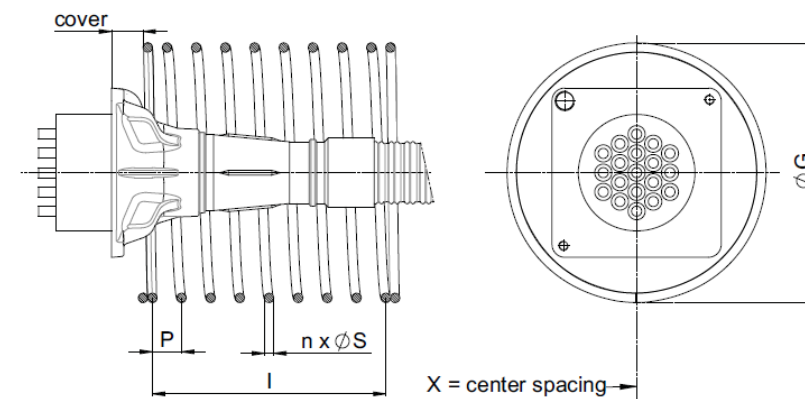
ANCHORAGE TYPE GC (Strand $F_{pk} = 260 / 265$ kN)

LOCAL ZONE REINFORCEMENT $f_y = 460$ N/mm²

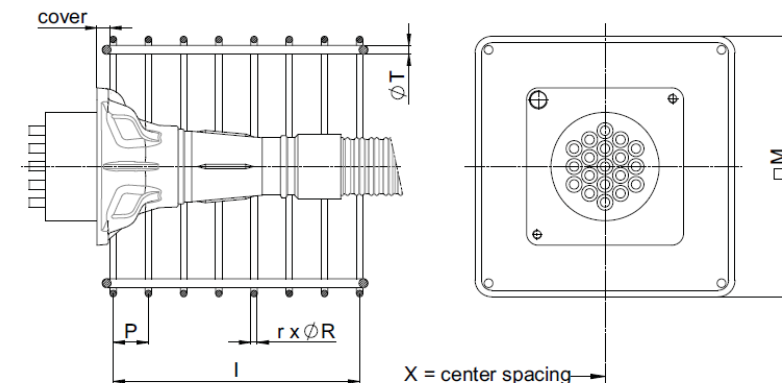
CONCRETE 50/62.5 MPa

Unit	A Spiral Reinforcement						B Stirrup Reinforcement						
	I	P	ØS	ØG	n	X	I	P	ØR	M	r	X	ØT
6-3	160	40	8	130	4	150	135	45	10	130	4	150	8
6-4	200	50	12	140	4	160	180	60	16	140	4	160	8
6-7	260	65	16	185	4	205	180	45	16	185	5	205	8
6-12	300	50	16	245	6	265	275	55	20	245	6	265	10
6-15	320	40	16	275	8	295	270	45	20	275	7	295	10
6-19	360	60	20	315	6	335	325	65	25	315	6	335	12
6-22	350	50	20	335	7	355	350	50	25	335	8	355	12
6-27	405	45	20	375	9	395	350	50	25	375	8	395	16
6-31	405	45	20	405	9	425	400	80	32	405	6	425	16
6-37	480	60	25	440	8	460	420	70	32	440	7	460	16
6-43	540	60	25	485	9	505	480	60	32	475	9	495	16
6-55	550	50	25	565	11	585	540	60	32	580	10	600	20

OPTION A - SPIRAL REINFORCEMENT

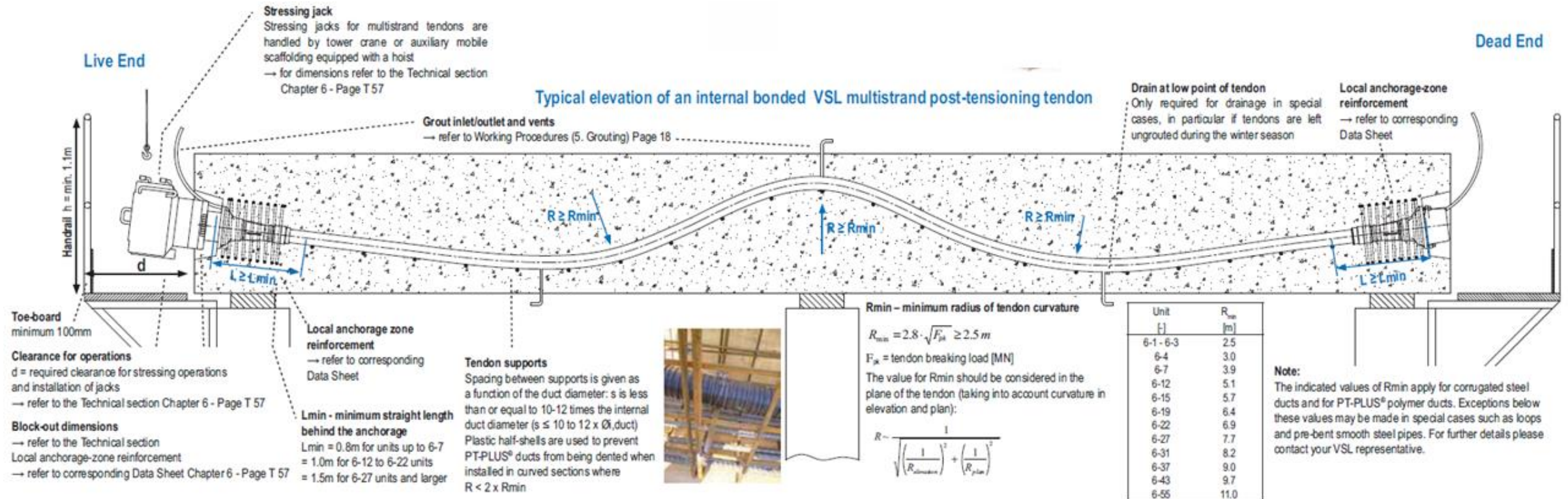


OPTION B - STIRRUP REINFORCEMENT



Prestressing Profile criterial and requirements

Profile criteria and requirements



Prestressing Profile criterial and requirements

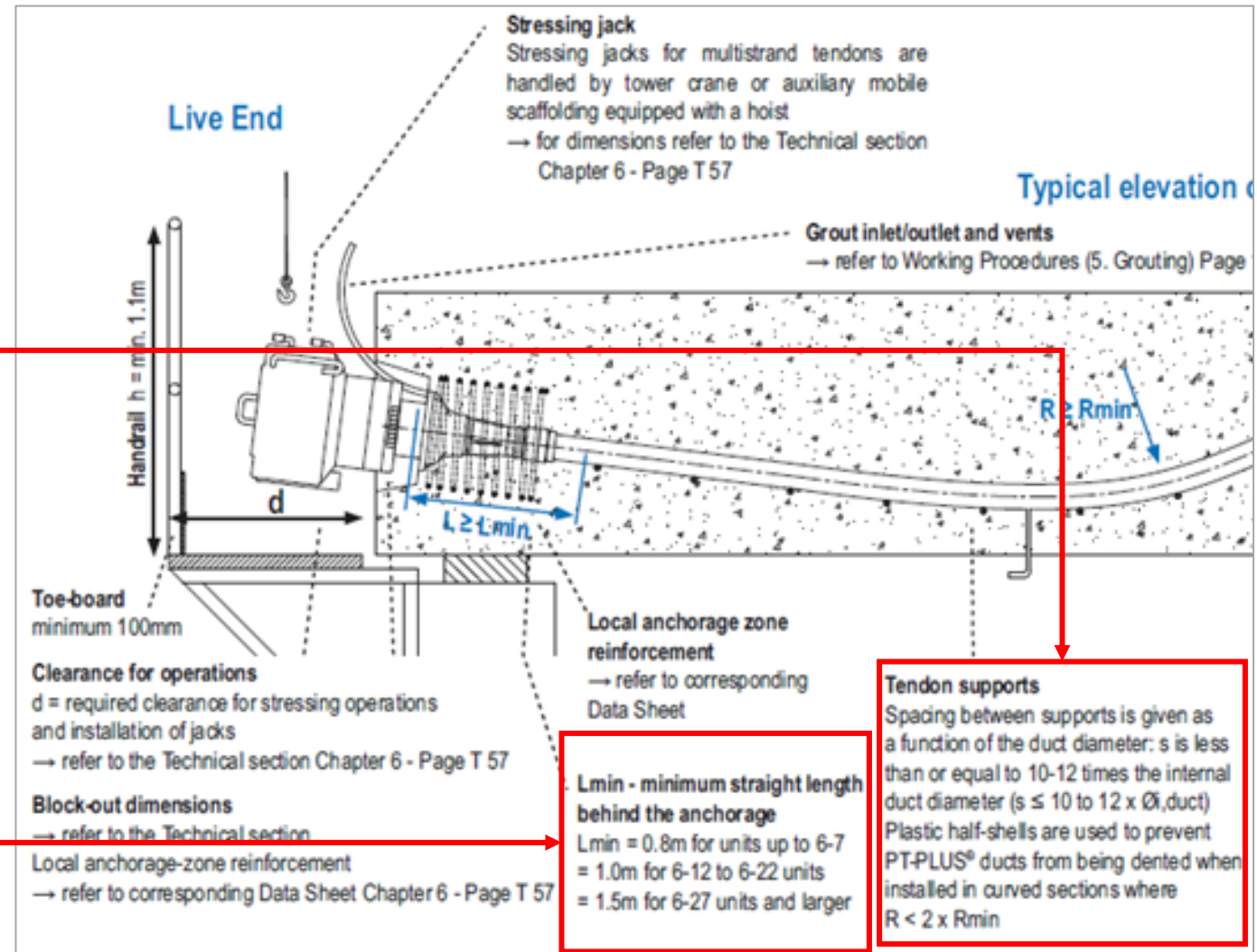
Profile criteria and requirements

Tendon supports

Spacing between supports is given as a function of the duct diameter: s is less than or equal to 10-12 times the internal duct diameter ($s \leq 10 \text{ to } 12 \times \varnothing_{i, \text{duct}}$)
Plastic half-shells are used to prevent PT-PLUS® ducts from being dented when installed in curved sections where $R < 2 \times R_{\min}$

L_{min} - minimum straight length behind the anchorage

$L_{\min} = 0.8\text{m}$ for units up to 6-7
 $= 1.0\text{m}$ for 6-12 to 6-22 units
 $= 1.5\text{m}$ for 6-27 units and larger



Prestressing Profile criterial and requirements

Profile criteria and requirements

R_{min} – minimum radius of tendon curvature

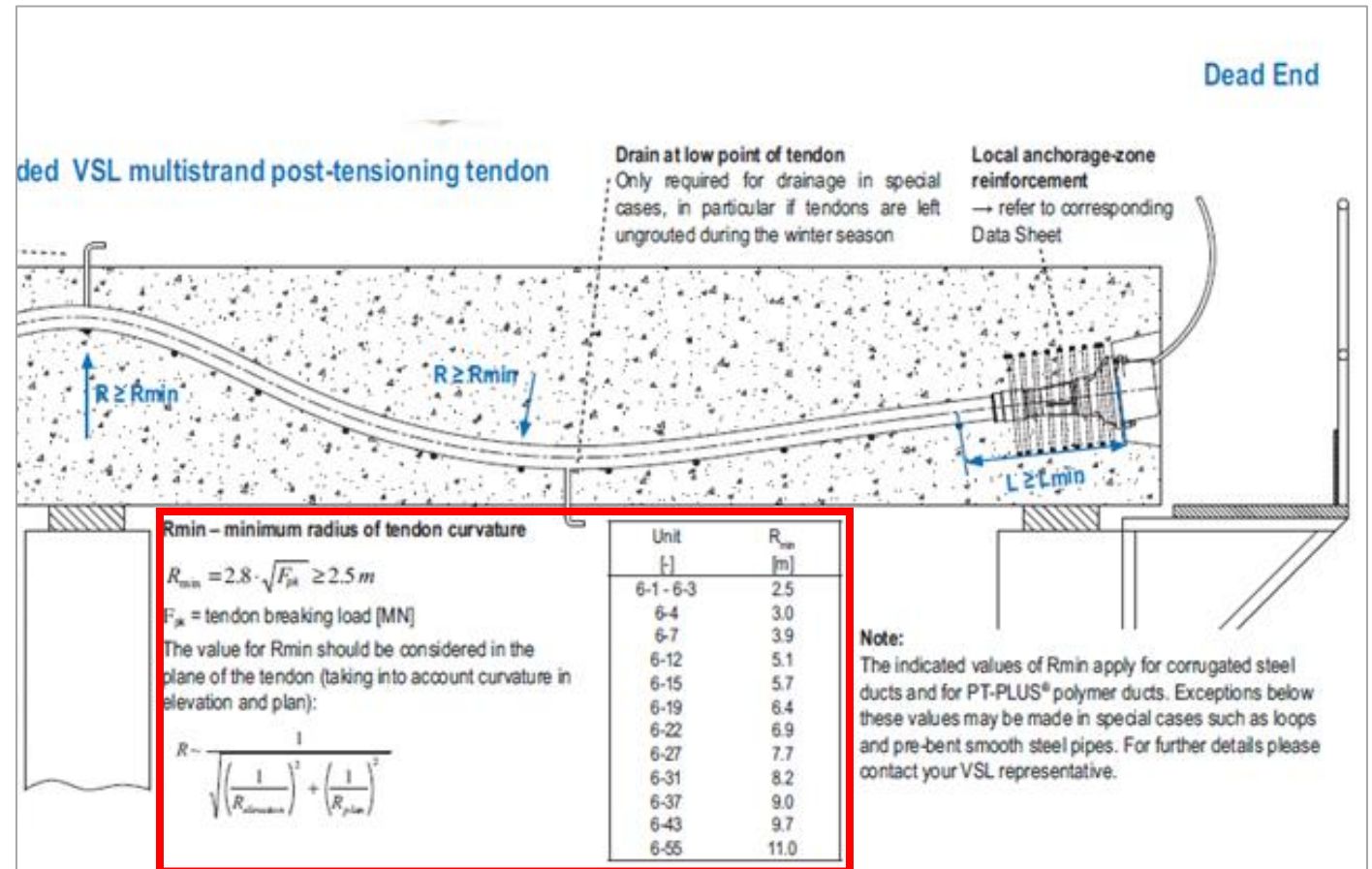
$$R_{\min} = 2.8 \cdot \sqrt{F_{pk}} \geq 2.5 \text{ m}$$

F_{pk} = tendon breaking load [MN]

The value for R_{min} should be considered in the plane of the tendon (taking into account curvature in elevation and plan):

$$R \sim \frac{1}{\sqrt{\left(\frac{1}{R_{\text{elevation}}}\right)^2 + \left(\frac{1}{R_{\text{plan}}}\right)^2}}$$

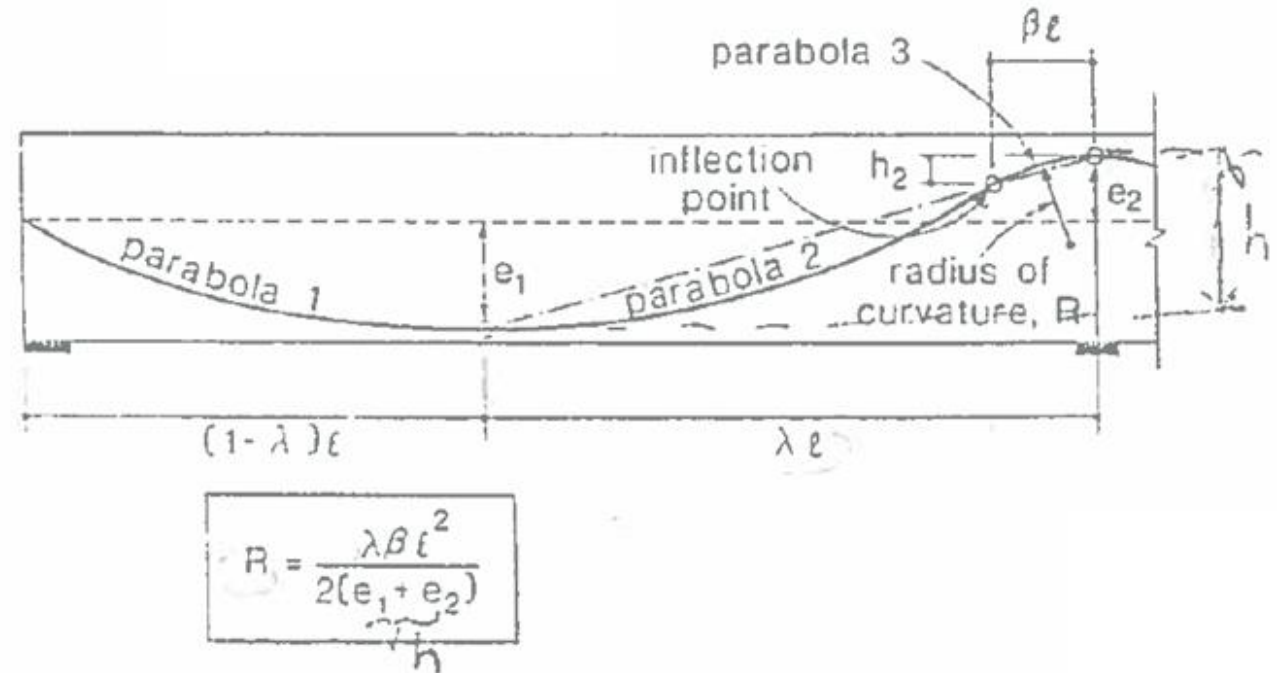
Unit [-]	R _{min} [m]
6-1 - 6-3	2.5
6-4	3.0
6-7	3.9
6-12	5.1
6-15	5.7
6-19	6.4
6-22	6.9
6-27	7.7
6-31	8.2
6-37	9.0
6-43	9.7
6-55	11.0



Prestressing Profile criterial and requirements

The radius of cable profile based on the control points.

- We typically use for exterior spans (the span after/before) expansion joint $\lambda = 0.6$
- For interior spans $\lambda = 0.5$
- Get the value of β to satisfy the required radius of the cable profile.



(b) Parabolic segments with compatible slopes

Figure 2-23 Geometry of parabolic profiles.